DESIGN AND CONSTRUCTION OF AN INTESTINAL NOISES ACQUISITION SYSTEM

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***Abstract* – This work shows the development of a tool useful in the characterization of intestinal noises (INN), this with the aim to identify certain pathologies of the digestive system in the nearby future. The proposed system has 8 audio transducers (7 for reception from INN and 1 for environmental noises (ENN). Signals are detected through a circuit that conditions them and then they are digitalized, filtered (eliminating ENN), compacted and finally stored for its further analysis.**
***Keywords* – Intestinal noises, audio transducers, 2nd order adaptive sampling method , adaptive filter.**

I. Introduction

Human body owns a complex net of communication which efficiently connect all internal systems as well as sends signals outside of it, to show the correct or incorrect function of those systems or even to prevent problems related to them. The body sends different kind of signals that can be detected by touch, smell, sight, sound and even taste. Occasionally these signals are hard to detect or quantify during a routine examination, then, special equipment designed for this purpose must be used. The INN as any other signals coming out from the body, carry information about how healthy is that patient. Such information is very important because it may be used for the diagnosis and prevention of illnesses.

Therefore there is a great interest on developing a prototype, which allows a deeper study in this field. At the "Laboratory for Medical Instrumentation in Cancerology" from Alexis Vautrin Centre, several prototypes have been tested. They were focused in the acquisition of INN [1]-[6], and they result in useful experiences for developing this acquisition system. Those works give up the following characteristics of INN:

- Intestinal noises are of variable frequency. Which ranges between 100 Hz and 1200 Hz.
- Their outcome frequency is variable during the measuring sessions.
- The amplitude of the signal is variable.
- Intensity of signals change depending on the localization of sensor at abdomen.

Also in those previous works there were established the main problems to be solved concerning the data acquisition and storing of information.

- Presence of noise (parasite signals) coming from several sources: environmental noises due to: technician, physiological sources, electromagnetic and the ones coming from the movement of the patient.
- Concerning about data storing, it is required a very big free space on the hard disk (4.5 GB HD for 24 hrs registration per patient), in order to work efficiently with those prototypes.

Now, with this characteristics and problems in evidence, a system which allows a depurated registration and a more efficient storing of INN was designed and developed.

II. Methodology

The system developed for data acquisition and storage of INN works based on: 8 audio channels, 7 of them are used to get the INN and the eighth one is used to get ENN.

The seven channels used to get INN, allow mathematic analysis of the captured signals for its further analysis, in order to identify paterns on this signals. The eight channel will allow getting the ENN signal to establish the correlation between both signals. This is to create the algorithm that will allow the elimination of noises present on the other seven channels, which are dedicated to get INN.

This system will be capable to store the seven channels of INN due to an algorithm of data compression and the information on the ENN channel will suppress the ENN that has been added to the acquired signal of INN.

2.1 The electronic circuit

The transducer (T) used was an electret's microphone, from Philips, mod. SBC ME600. coupled by air. The coupler (C) was made of extra soft silicon of low viscosity, with the form shown in fig. 1.

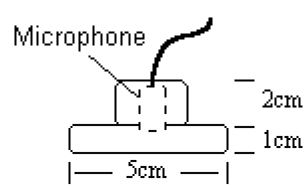

Fig. 1. Dimensions of developed coupler.

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Then it was carried out the analysis of the response from the microphone installed inside the coupler, verifying the possibility of resonant frequencies due to the cavity inside the coupler, as well as the deformation of the microphone's response.

Once the signal is detected, it must be conditioned (rearranged) for its later acquisition through a data acquisition card. The conditioning circuit has a preamplifier (PA), a bandpass filter (BPF) and an output regulated amplifier (A V/G).

The bandpass filter is a 2nd order Butherworth filter, which was designed with a bandwidth of 70 Hz to 1200 Hz, this will eliminate the electromagnetic noise signals and will limit the maximum input frequency disabling aliasing effect [10].

Sampling frequency selected for each channel was of 4096 samples/sec each, with a resolution of 12 bits. Complete circuit [11] has eight detection and conditioning lines and a data acquisition card such as in fig. 2.

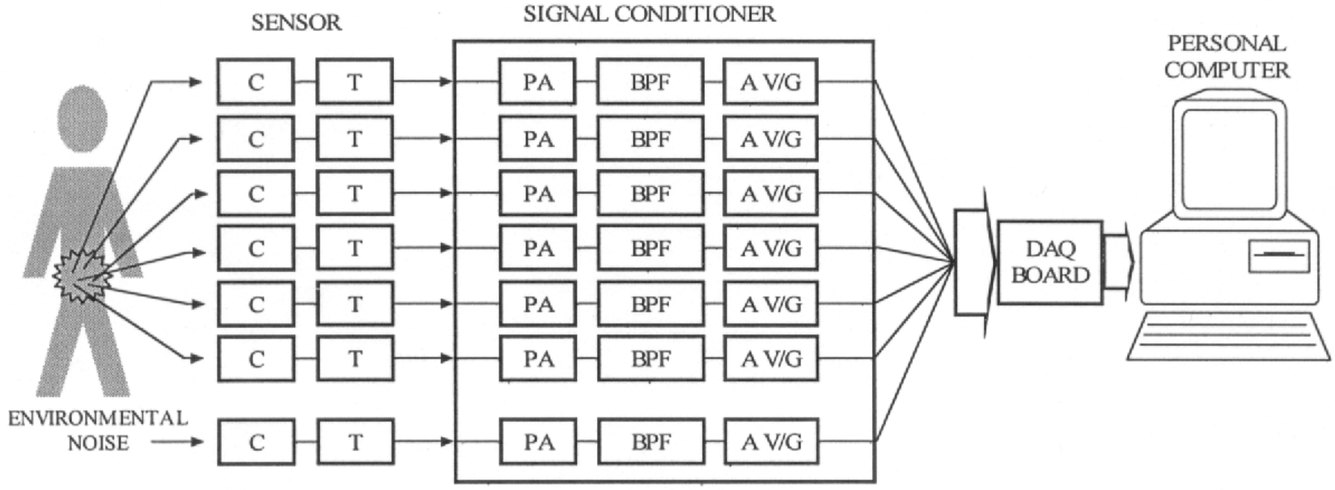

Fig. 2. Diagram of detection system and INN acquisition block.

2.2 Acquisition program: the filtered algorithm and data compression

For processing biological signals, the adaptive filtering methods are useful for eliminating noise of those signals [12], [13]. Fig. 3 shows the general model of an adaptive filter for noise elimination [14].

With this system, we can represent the INN+ENN (primary entrance) as well as $s(nT)+n_0(nT)$. The ENN is additive and is considered not to be correlated to primary signals. A second input $n_1(nT)$ feeds the filter and produces an output $\zeta(nT)$ which is a very close estimation of $n_0(nT)$. Noise $n_1(nT)$ shows an unknown correlation to $n_0(nT)$.

Output $\zeta(nT)$ is subtracted from primary input, generating an output $y(nT)$. This output signal is known as error $\varepsilon(nT)$ which is used to adjust the coefficients from adaptive filter $\{w(1,...,p)\}$. The parameters of filter were determined in base to the papers of M. Schablowski [6].

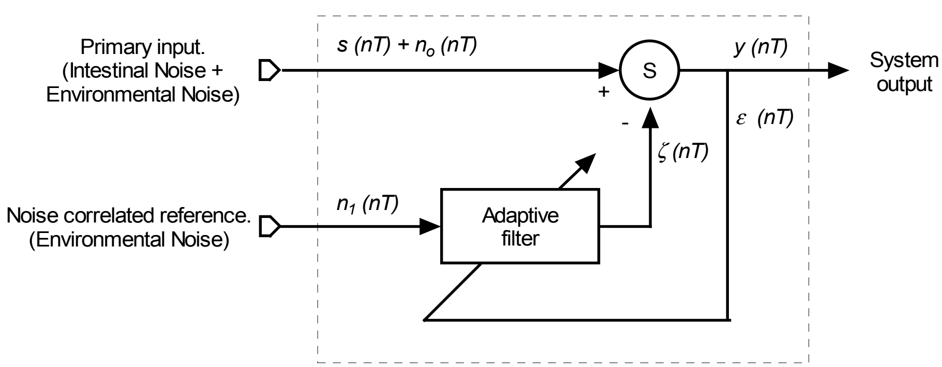

Fig. 3. Adaptive filter structure for noise cancellation.

The method used to compress data acquisition is based on the Method of Adaptive Sampling 2nd Order [15]. The algorithm developed shows only a small variation towards the original method with which it is possible to know the time elapsed at any point of registration since the INN began.

2.3 Positioning of sensors at the abdomen of patient

To fix sensors over patient's abdomen a Tegaderm 6 cm X 6 cm adhesive tape from 3M was used. Such transparent adhesive tape is waterproof but allows gas exchange and allows perspiration from patients skin. Some choices for positioning sensors at patient's abdomen are shown in fig. 4.

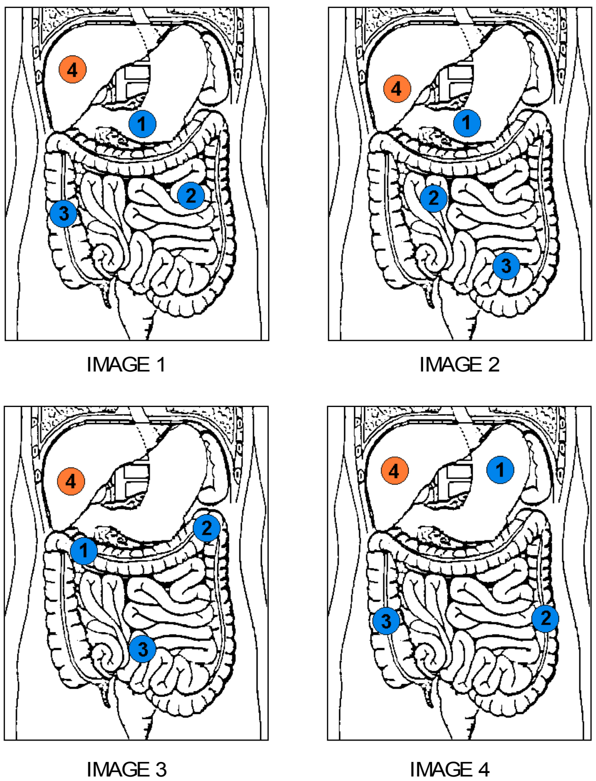

Fig. 4. Choices of how to position 3 transducers for INN detection and 1 transducer for ENN detection.

2.4 The INN analysis software

Once the acquired signals have been stored, they can be visualized under to observation methods: normal view, which allows visualizing intervals in 4 seconds and zoom view which allow visualizing 4 seconds in 30 intervals each at $125x10^{-3}$ sec.

III. RESULTS

Once the system was finished, was detected that the adaptive filtering requires a type of processing which does not allow reliable data acquisition from the 8 audio channels, therefore the reduction to 4 channels (3 for INN and 1 for ENN).

After the system started, several measurements were made from a 25 year old healthy male. Figure 8 shows one of the INN acquired during one of the recording sessions.

The signal captured has a bandwidth of 100 Hz to 1000 Hz, but this signal presents still ENN, this is because the filter window is to small and does not allow a good tuning of the filter with which a cancellation of environmental noises might take place. The fig. 5 shows an example of an INN captured.

Satisfactory results were given by compression algorithm. Efficiency of this algorithm varies depending on the amount of noises coming from system (INN + ENN). This is the reason why a better filter is required to cancel environmental noise and to avoid saving unnecessary information.

The coupler gave satisfactory results as well. There are no significant changes on the detected signals. The tape used for fixing it was excellent for that it keep the sensor at the patients stomach for more than 5 hours.

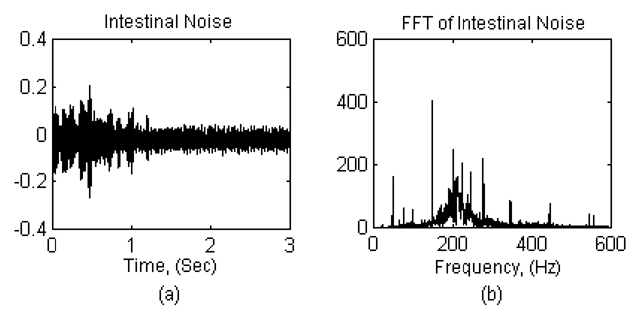

Fig. 5. (a) Example of an INN captured in one session, (b) Captured signal FFT.

IV. CONCLUSION

Analysis of INN has future on the diagnosis field. Verifying the state of art no similar studies of projects were found. Studying the signals acquired in detail, important information could be found for example in the topography of the signal, its intensity, its spectral density and the periodicity in which the signal appears among others.

Possible applications of the INN monitoring:

- Detect intestinal mobility after abdominal surgery.
- Detect intestinal occlusion.
- Evaluate functionality of quirurgical implantations.
- Determine mobility of an internal organ.
- Determine problems in the intestinal mobility.
- Evaluate possible changes in intestinal mobility due to the use of drugs.

- Detect some pathology related to the state of intestines.

In this work it was revealed that in order to work in suggested applications, it is necessary to modify the system as follows:

- The positioning of the sensors over the patient is something to be still investigated. An ideal position of the microphones for getting the signal of INN is to be found. While another position where the noise cancellation is optimized has to be found for the ENN sensor.
- A more efficient algorithm for noise reduction must be found and must have above all a smaller amount of operations so that it could be use in real time.
- Sampling frequency is expected to be reduced down to 2048 samples/sec, with which the number of operations will be reduced to half and there for also the space needed for storing the signals.

Concluding, due to there are no other previous works in this area than the mentioned above, it is necessary to develop more studies related to de Intestinal noises acquisition system before definitive conclusions are made. The developed system in this work, allows a long term recording with certain amount of environmental noise but it could be minimized as soon as the filtering algorithm might be optimized. Sampling frequency could also be lowered when the real bandwidth for INN were determined. When this is achieved, reliable measurements for analysis and for determination of INN parameters will be made.

References

[1] P. Rauch, "Spectrosonographie des Bruits de l'abdomen," *Techincal Report*. Nancy, France. 1994.

[2] F. Bornant, D. Della-Vittoria, "Mise au point d'un Borborygmètre," *Techincal Report*. Nancy, France. 1994.

[3] C. Vanhoute, "Elaboration d'un dispositif pour la saisie et l'etude des bruits intestinaux," *Techincal Report*. Nancy, France. 1994.

[4] B. Gwendoline, "Contribution a l'elaboration d'un systeme pour l'etude des bruits intestinaux," *Techincal Report*. Nancy, France. 1996.

[5] W. Pascal, "Rapport de stage," *Techincal Report*. Nancy, France. 1996.

[6] M. Schablowski, "Etude de différents filtres numériques adaptés aux traitements des bruits intestinaux," *Technical Report*. Nancy, France. 1995.

[7] M. Abella, J. Formolo, D. G. Penney, "Comparison of the acoustic properties of six popular stethoscopes," *J. Acoust. Soc. Am*. Vol 91 No. 4. 1992.

[8] B. Champagne, "Simulation of the response of multiple microphones to a moving point source," *Applied Acoustics*, Vol. 42, 1994, pp. 313-32.

[9] C. K. Druzgalsky, R. L. Donnerberg, R. M. Campbell, "Techniques of recording respiratory sounds," *Journal of Clinical Engineering*. Vol. 5 No. 4. Oct-Dec 1980.

[10] A. Oppenheim, R. Shafer, "Digital Signal Processing," Ed. Prentice Hall. USA. 1975.

[11] J. E. Chong, "Design and construction of a system for the study of intestinal noises," *Techincal Report*. Nancy, France. 1997.

[12] W. Tompkins, "Biomedical Digital Signal Processing," Ed. Prentice Hall. USA. 1993.

[13] V. K. Iyer, P. A. Ramamoorthy, Y. Ploysongsang, "Characteristics of normal loung sounds after adaptive filtering," *IEEE Trans. Biomed. Eng.*, Vol. 36, No. 11, 1989.

[14] S. Haykin, "Adaptive Signal Processing," Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1986.

[15] A. Cohen, "Biomedical Signal Processing Vol. I, Time and Frequency Domains Analysis," CRC Press, Inc.